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Design and Simulation of a Circular Microstrip Patch Antenna for Breast Cancer Diagnosis

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Abstract

This paper analyzes different parameters for detecting breast cancer at a curable stage using the software High-Frequency Structure Simulator (HFSS). The model consists of a microstrip circular patch antenna, breast model, and tumor. This model shows that tumors present in the breast can be detected by observing the change in the distribution of volume current density, the electric field, and the magnetic field of the breast in the presence of a tumor and the absence of a tumor. The proposed antennas fed a microstrip line on the FR4_Epoxy substrate with a size of substrate width 28 mm and substrate length 30 mm, the thickness of 0.8 mm, and relative dielectric constant of 4.4 with the radius of 7 mm. The antenna that we designed has an operating range from 3.26 GHz to 12.50 GHz, which in the entire UWB (3.1-10.6 GHz) with the return loss -19.15 dB and voltage standing wave ratio 1.21. The proposed model shows that, in the absence of a tumor, the maximum current density, electric field, and magnetic field of the breast are 1040.4 A/m^2,260.10 V/m and 3.038 A/m, respectively. On the other hand, in the presence of a tumor, the maximum current density, electric field, and magnetic field of the breast are 1093.1 A/m^2,273.29 V/m, and 3.09 A/m, respectively. These techniques used for breast cancer detection are competitively easier, safer, and low cost.

Keywords – *Breast cancer, Tumor Cells, Circular Microstrip Patch Antenna, Cancer Detection, FR4_Epoxy Substrate, HFSS.*

I. INTRODUCTION

Breast cancer is the most common, life-threatening, high incidence, and a second leading cause of cancer death among the world's women. Because of not to diagnose at a curable stage, new cases of breast cancer are diagnosed, and many women die of breast cancer each year in Bangladesh. The key factor in treatment is the early stage of reliably diagnosis cancer reliably. Statistics reveal that approximately 13.2 million deaths of cancer are expected in 2030 [1]. The concept of the microstrip antenna was first introduced in the 1950s [2]. However, this idea had to wait nearly 20 years to be realized after developing the printed circuit board (PCB) technology in the 1970s [3]. Since then, microstrip antennas are considered as the most common types of antennas due to their obvious advantages of a lightweight, low cost, low profile, planar configuration, simple to conform, superior portability, suitable for arrays, easy for fabrication, and easy to microwave integration. Microwave imaging to detect breast cancer is an encouraging method. There is much technique for identifying breast cancer, such as X-ray mammography ultrasound, tomography, and MRI. However, they have some drawbacks. For example, between 4 % and 34 % of all breast cancers are missed due to contrast poor malignant/benign cancer tissue [4]. These methods are not preferred, especially for younger women, because of ionizing radiation. Recently, microwave imaging has been applied to the detection of breast cancer. The contrast of electrical properties is focused on this paper for cancer detection with microwave imaging. The calculations and simulations performed on the flexible microstrip patch antenna are found and noted in this paper and its application for breast cancer diagnosis.

Key functions for microwave-based breast cancer would be (a) low health risk, (b) low cost, (c) ability to detect breast cancer at a curable level, (d) sensitivity to tumors and particular to malignancies, (e) minimal disc omfort in women's tolerability lesions (f) simple understanding, and reliable outcomes. This particular approach is comparatively easier and better than mammography and tomography, in which we use high-intensity X-rays to detect breast cancer. In this paper, the model shows that tumors present in the breast can be detected by observing the change in the distribution of volume current density, the electric field, and the magnetic field of the breast in the presence of a tumor and the absence of a tumor. In the coming section, we would discuss the theory of various parameters, designing a circular microstrip patch antenna, and the simulation of a cancer diagnosis model.

II. CIRCULAR MICROSTRIP PATCH ANTENNA DESIGN

The proposed circular microstrip patch antenna fed by a microstrip line is shown in Fig.1, which is printed on the FR4 Epoxy substrate with a size of Substrate width 28mm and substrate length 30 mm (i.e., SubW×SubL = 28×30 mm$^{2)}$, the thickness of 0.8mm and relative dielectric constant of 4.4, length of the feed line 14 mm, and width of the feed line 2.46 mm. The proposed antenna is connected to a connector for signal transmission. The patch is connected to a microstrip feed line with a radius of 7 mm. A partial ground plane is printed on the bottom surface of the substrate, which is the same width as the substrate width (SubW). To cover a much better frequency band total number of four slots has been taken on the ground. All the Optimized Parameters and corresponding values for the proposed circular microstrip patch antenna are listed in Table 1.

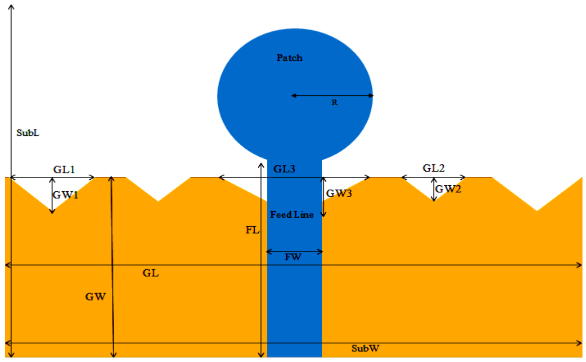
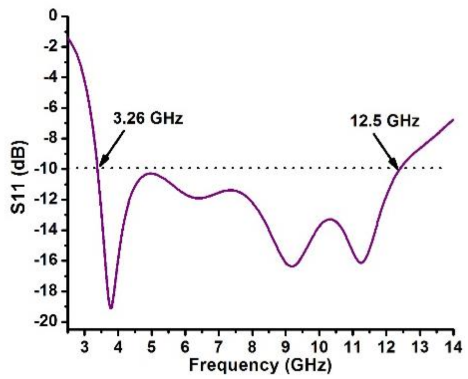


Figure-1:Optimized structured of the proposed antenna

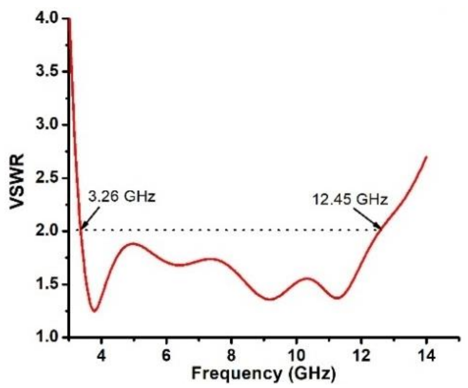
Table 1: Parameters and Values for the Proposed Antenna

Parameter	Value(mm)	Parameter	Value(mm)
SubL	30	GL1	2
SubW	28	GW1	5.5
SubH	0.8	GL2	1
GL	13	GW2	3.5
GW	28	GL3	3
FL	14	GW3	7
FW	2	r(radius)	7

The simulated return loss (S11) and VSWR of the proposed circular microstrip patch antenna system are shown in Fig.2 (a) and (b), respectively.



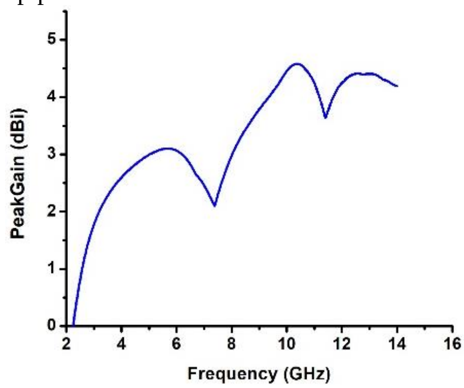
(a)



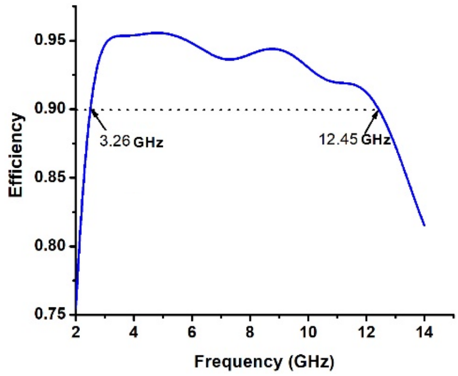
(b)

Figure 2: (a) Return loss (S11), and (b) VSWR of the proposed antenna

From Fig.2, It is observed that the proposed antenna led to a return loss of -10dB from 3.26 GHz to 12.5 GHz, and the voltage standing wave ratio (VSWR) is a function of the return loss (S11), which describes the power reflected from the antenna. The VSWR for the proposed circular microstrip patch antenna is 1.21.



(a)



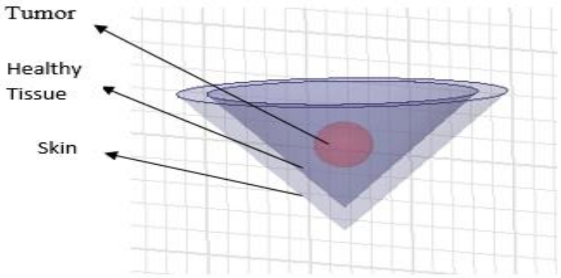
(b)

Figure 3: (a) Gain, and (b) Efficiency of the proposed antenna

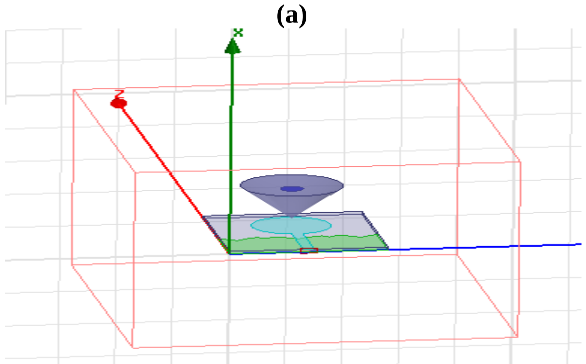
The simulated peak gain of the proposed circular microstrip patch antenna system is plotted in Fig.3 (a). The graph shows enough high peak gain from 2 dBi to 4.7dBi that is suitable for UWB applications. The simulated efficiency of the proposed circular microstrip patch antenna system is plotted in Fig.3 (b). From the graph, we see that the coverage band of frequency is more than 0.90, which means the proposed antenna's efficiency is more than 90%.

III. DESIGN OF CANCER DIAGNOSIS MODEL

Different designs of breast phantoms have been used by researchers [5-7]. All these phantoms are characterized by essential electrical properties, which are the relative permittivity $\varepsilon_r$and conductivity σ. In this paper, we adopted a cone shape to model the breast phantom composed of skin with the lower radius of the cone is 0 mm, and the upper radius of the cone is 11 mm. A fatty tissue named healthy tissue with the lower radius of the cone is 0 mm, and the upper radius of the cone is 9 mm. The gap on all sides between the skin and healthy tissue is 2mm. Aspherical tumor placed in the middle of the breast with a 2 mm radius, as shown in Fig.4 (a), and the different electrical properties of the breast and tumor are presented in Table 2.



(a)



(b)

Figure 4: (a) Breast model (b) Breast model with antenna

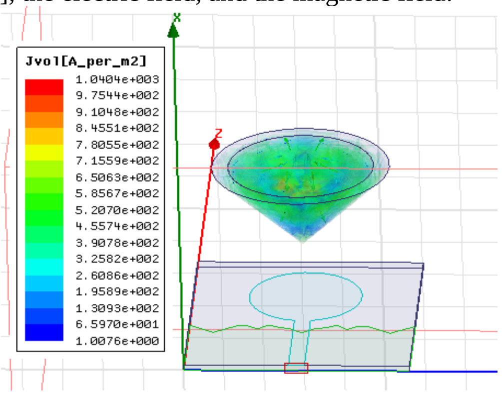
Table 2: Electrical Property of Breast Tissue

Breast Tissue	Dielectric	Conductivity(S/m)
Healthy tissue	10.5	0.4
Skin	36	4
Tumor	50	4

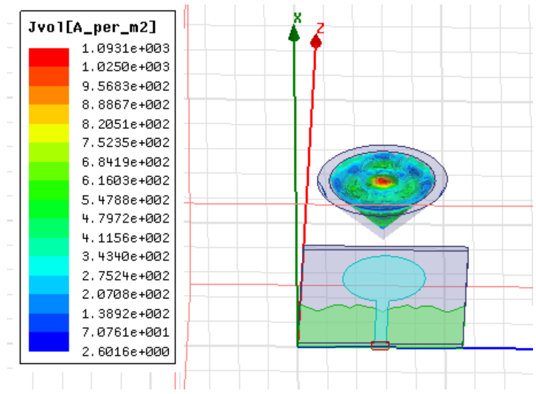
We have designed a cancer diagnosis model that consists of a circular microstrip patch antenna and breast model, which is placed 10 mm distant from the proposed antenna shown in Fig.4 (b). The structure is modeled and simulated without a tumor and with a tumor, and the next segment discusses potential outcomes.

RESULTS AND DISCUSSION

When the tumor is considered inside the phantom, the simulated results are expected to represent different values. The results will be determined respectively by observing the volume current density [A/m^2], the electric field, and the magnetic field.



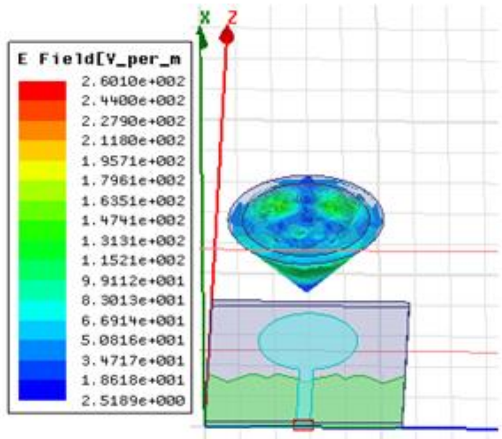
(a)



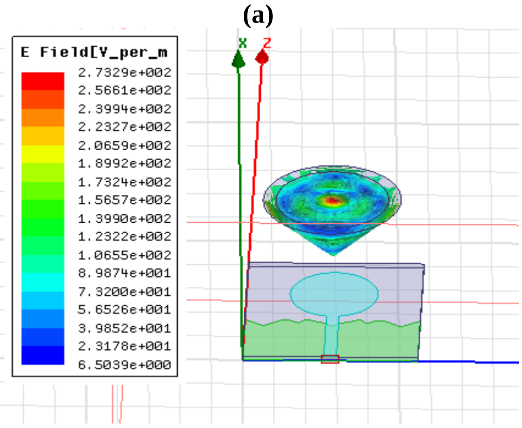
(b)

Figure 5: Tumor effect on the volume of current density. (a) Breast model without a tumor (b) Breast model with a tumor

Figure 5 (a) illustrates the current density distribution in the breast without a tumor. It is easy to find that the maximum current density in the breast is 1040.4 A/m^2. When inserting a tumor with a radius of 2 mm and simulating the designed model, the maximum current density is 1093.1 A/m^2, as shown in Figure 5 (b). The difference in current density when the tumor exists is greater than 52.7 A/m^2. It means the breast has more structure than the tumorless breast.



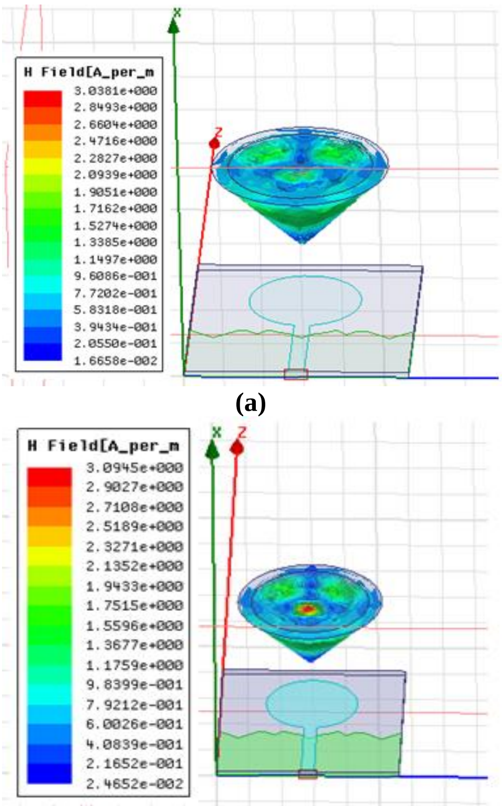
(a)



(b)

Figure 6: Tumor effect on the electric field. (a) Breast model without a tumor; (b) Breast model with a tumor

Figure 6 (a) shows the distribution of the electric field without a tumor in the breast. The maximum electric field in the breast can be found as 260.10 V/m. The electric field distribution is shown in Figure 6 (b), after inserting the tumor and simulating the design model. The breast's maximum electric field is 273.29 V/m, where the difference in the electric field when the tumor is presented within the breast phantom is greater than 13.19 V/m



(a)

(b)

Figure 7: Tumor effect on the magnetic field. (a) Breast model without a tumor; (b) Breast model with a tumor

Figure 7 (a) indicates magnetic field distribution in the breast without a tumor. The maximum magnetic field in the breast can be found as 3.038 A/m. The distribution of the magnetic field is shown in Figure 7(b) after the tumor is implanted and the design model simulated. The maximum magnetic field of the breast is 3.09 A/m, where the difference in the magnetic field when the tumor is present inside the phantom of the breast is greater than 0.052 A/m. The latest results of this work indicate that only a single antenna is used as the ultimate goal; a low cost and less complexity would result. In other words, two antennas are used in a variety of published studies, instead of a single antenna (current work), to determine where the purpose of the first antenna is to transmit electromagnetic radiation while the second is to receive the radiation. Therefore the solution is based on using S21 rather than S11 (current work).

IV. CONCLUSION

Over the past few years, microwave breast imaging has been a dynamic research field and has attracted significant recent attention. The thought of using a UWB circular microstrip patch antenna to detect the breast tumor is investigated in this paper. It is observed from the study that, in breast structure without tumor, the current density distribution, electric field, and magnetic field values are 1040.4 A/m^2, 260.10 V/m, and 3.038 A/m, respectively. On the other hand, in breast structure with a tumor, the current density distribution, electric field, and magnetic field values are 1093.1 A/m^2, 273.29 V/m, and 3.09 A/m, respectively. These methods, which are used to detect cancer within the breast, are competitively simpler, safer, and low cost. Tumor detection can save many lives in time.

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